NEWTON'S APPLE®
Multimedia

Gravity

Rockets

Teacher's Guide

NEWTON'S APPLE Multimedia

Table of Contents

Introduction

Welcome to the *Newton's Apple Multimedia Collection*™!

Drawing from material shown on public television's Emmy-award-winning science series, the multimedia collection covers a wide variety of topics in earth and space science, physical science, life science, and health. Each module of the *Newton's Apple Multimedia Collection* contains a CD-ROM, a printed Teacher's Guide, a video with two *Newton's* ® *Apple* segments and a scientist profile, and a tutorial video.

The Teacher's Guide provides three inquiry-based activities for each of the topics, background information, assessment, and a bibliography of additional resources.

The CD-ROM holds a wealth of information that you and your students can use to enhance science learning. Here's what you'll find on the CD-ROM:

- two full video segments from *Newton's Apple*
- additional visual resources for each of the *Newton's Apple* topics
- background information on each topic
- a video profile of a living scientist working in a field related to the *Newton's Apple* segments
- an Adobe Acrobat® file containing the teacher's manual along with student reproducibles
- UGather® and UPresent® software that allows you and your students to create multimedia presentations
- QuickTime® 3.0, QuickTime® 3 Pro, and Adobe Acrobat® Reader 3.0 installers in case you need to update your current software

The *Newton's Apple Multimedia Collection* is designed to be used by a teacher guiding a class of students. Because the videos on the CD-ROM are intended to be integrated with your instruction, you may find it helpful to connect your computer to a projection system or a monitor that is large enough to be viewed by the entire class. We have included a videotape of the segments so that you can use a VCR if it is more convenient. Although the CD-ROM was designed for teachers, it can also be used by individuals or cooperative groups.

With the help of many classroom science teachers, the staff at *Newton's Apple* has developed a set of lessons, activities, and assessments for each video segment. The content and pedagogy conform with the National Science Education Standards and most state and local curriculum frameworks. This Teacher's Guide presents lessons using an inquiry-based approach.

If you are an experienced teacher, you will find material that will help you expand your instructional program. If you are new to inquiry-based instruction, you will find information that will help you develop successful instructional strategies, consistent with the National Science Education Standards. Whether you are new to inquiry-based instruction or have been using inquiry for years, this guide will help your students succeed in science.

WE SUPPORT THE NATIONAL SCIENCE EDUCATION STANDARDS

The *National Science Education Standards* published by the National Research Council in 1996 help us look at science education in a new light. Students are no longer merely passive receivers of information recorded on a textbook page or handed down by a teacher. The Standards call for students to become active participants in their own learning process, with teachers working as facilitators and coaches.

Newton's Apple's goal is to provide you with sound activities that will supplement your curriculum and help you integrate technology into your classroom. The activities have been field tested by a cross section of teachers from around the country. Some of the activities are more basic; other activities are more challenging. We don't expect that every teacher will use every activity. You choose the ones you need for your educational objectives.

Teacher's Guide

We suggest you take a few minutes to look through this Teacher's Guide to familiarize yourself with its features.

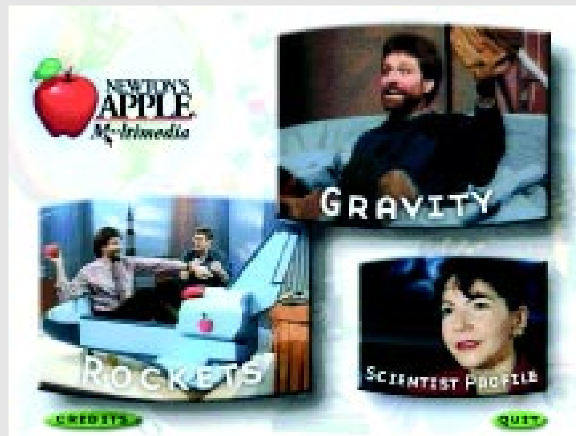
Each lesson follows the same format. The first page provides an overview of the activity, learning objectives, a list of materials, and a glossary of important terms. The next two pages present a lesson plan in three parts: ENGAGE, EXPLORE, and EVALUATE.

- ENGAGE presents discussion questions to get the students involved in the topic. Video clips from the *Newton's Apple* segment are integrated into this section of the lesson.
- EXPLORE gives you the information you need to facilitate the student activity.
- EVALUATE provides questions for the students to think about following the activity. Many of the activities in the collection are open-ended and provide excellent opportunities for performance assessment.

GUIDE ON THE SIDE and TRY THIS are features that provide classroom management tips for the activity and extension activities.

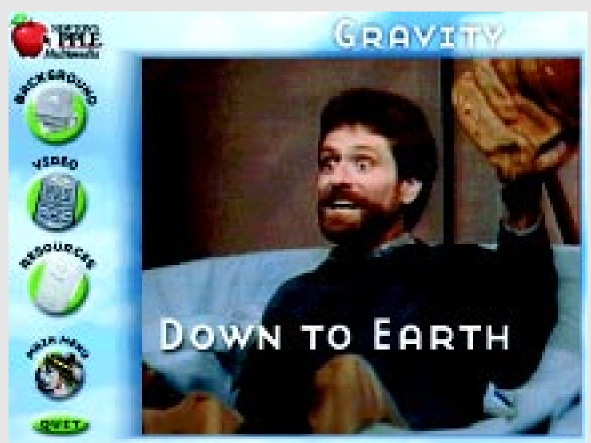
Using the CD-ROM

When you run the *Newton's Apple* CD-ROM, you will find a main menu screen that allows you to choose either of the two *Newton's Apple* topics or the scientist profile. Simply click on one of the pictures to bring up the menu for that topic.



Main Menu

Once you have chosen your topic, use the navigation buttons down the left side of the screen to choose the information you want to display.



Topic Menu

The Background button brings up a short essay that reviews the basic science concepts of the topic. This is the same essay that is in the Teacher's Guide.

Playing the Video

The Video button allows you to choose several different clips from the video segment. We have selected short video clips to complement active classroom discussions and promote independent thinking and inquiry. Each video begins with a short introduction to the subject that asks several questions. These introductory clips can spark discussion at the beginning of the lesson. The Teacher's Guide for each activity presents specific strategies that will help you engage your students before showing the video. Each of the individual clips are used with the lesson plans for the activities. The lesson plan identifies which clip to play with each activity.

Video Menu

Once you select a video and it loads, you'll see the first frame of the video segment. The video must be started with the arrow at the left end of the scroll bar. As you play the video, you can pause, reverse, or advance to any part of the video with the scroll bar. You can return to the Clips Menu by clicking on the Video button.

Multimedia Tools

The *Newton's Apple* staff has designed a product that is flexible, so that you can use it in many different ways. All of the video clips used in the program are available for you to use outside the program. You may combine them with other resources to create your own multimedia presentations. You will find all the video clips in folders on the CD-ROM. You may use these clips for classroom use only. They may not be repackaged and sold in any form.

You will also find a folder for UGather™ and UPresent™. These two pieces of software were developed by the University of Minnesota. They allow you to create and store multimedia presentations. All of the information for installing and using the software can be found in the folder. There is an Adobe Acrobat® file that allows you to read or print the entire user's manual for the software. We hope you will use these valuable tools to enhance your teaching. Students may also wish to use the software to create presentations or other projects for the class.

Technical Information

Refer to the notes on the CD-ROM case for information concerning system requirements. Directions for installing and running the program are also provided there.

Make sure you have the most current versions of QuickTime® and Adobe Acrobat® Reader installed on your hard drive. The installation programs for QuickTime 3, QuickTime Pro, and Acrobat Reader 3.0 can be found on the CD-ROM. Double-click on the icons and follow the instructions for installation. We recommend installing these applications before running the *Newton's Apple Multimedia* program.

Trouble Shooting

There are several Read-Me files on the CD-ROM. The information found there covers most of the problems that you might encounter while using the program.

Integrating Multimedia

We suggest that you have the CD-ROM loaded and the program running before class. Select the video and allow it to load. The video usually loads within a couple of seconds, but we recommend pre-loading it to save time.

All of the video segments are captioned in English. The captions appear in a box at the bottom of the video window. You can choose to play the clips in either English or Spanish by clicking one of the buttons at the bottom right of the screen. (You can also choose Spanish or English soundtracks for the scientist profile.)

The Resources button provides you with four additional resources. There are additional video clips, charts, graphs, slide shows, and graphics to help you teach the science content of the unit.

Resources Menu

The other navigation buttons on the left side of the window allow you to go back to the Main Menu or to exit the program.

Blast Off!

How do rockets get off the ground? Do they push against the earth? How do rockets move through space? How do Newton's laws of motion help us understand rockets?

Themes and Concepts

- motion and forces
- Newton's laws of motion
- transfer of energy

National Science Education Content Standards

Content Standard A: Students should develop abilities necessary to do scientific inquiry.
Content Standard B: Students should develop an understanding of motions and forces.
Content Standard B: Students should develop an understanding of transfer of energy.
Content Standard G: Students should develop an understanding of the nature of science.

Activities

1. *Newton's Slider—approx. 20 min. prep; 60 min. class time*
How do Newton's laws of motion apply to the movement of a rocket? Simulate the movement of a rocket to discover how a basic rule of physics works and where a rocket gets its push!

2. *Lift Off!—approx. 15 min. prep; 45 min. class time*
What is the key to keeping a rocket stable? Design and construct your own rocket and test its stability. Discover how devices like fins help guide a rocket through the atmosphere.

3. *Rocket Power—approx. 20 min. prep; 50 min. class time*
What does a rocket engine do to make it move in space? With the help of a balloon-powered vehicle, explore how expanding gases are all that's needed to provide thrust.

More Information

Internet

Newton's Apple
http://www.ktca.org/newtons
(The official *Newton's Apple* web site with information about the show and a searchable database of science ideas and activities.)

National Air and Space Museum — How Things Fly
http://www.nasm.edu/GALLERIES/GAL109/NEWHTF/HTF030.HTM
(A great site on everything from how things orbit to why people can't fly.)

NASA Sites
http://spacelink.nasa.gov/Instructional.Materials/Curriculum.Support/Technology/Educator.Guides.and.Activities/.index.html
(Superb resource. Everything every teacher needs to know about rockets and space flight. The site features downloadable lesson plans and activities on rockets and space.)

http://nssdc.gsfc.nasa.gov/about/about_wdc-a.html
(The web site for the World Data Center for Rockets and Satellites. A good source of information on rockets, rocket launches, and the history of rockets.)

http://www.lerc.nasa.gov/www/k-12/TRC/RocketsRocketActivitiesHome.html
(An additional NASA site that has a wealth of classroom activities on rockets.)

Indiana University
http://mirkwood.ucs.indiana.edu/space/rocketry.htm
(A brief history of the development of the rocket.)

Internet Search Words

rockets, NASA

Books

Maurer, R. (1995) *Rocket! How a Toy Launched the Space Age* Crown Publishing. New York.
(A good overview of the historic developments in rocketry.)

Van Milligan, T. (1995) *Model Rocket Design and Construction*. Kalmbach Books, Waukesha, WI.
(An overview of the types of model rockets that are available.)

Wiese, J. (1995) *Rocket Science*. John Wiley & Sons, Inc. New York.
(A great book of high flying activities that students can build)

Winter, F. (1990) *The First Golden Age of Rocketry: Rockets of the Nineteenth Century*. Smithsonian Institution Press, Washington, D.C.
(Overview of early rockets)

Kagan, D. Buchholtz, L., and Klein, L. (1995) *"Soda-bottle Water Rockets." The Physics Teacher,* March, v 33 n 3 (Give details on the construction of inexpensive rockets to demonstrate Newton's laws of motion.)

Other Resources

Dr. Robert H. Goddard Space Flight Center
NASA/GSFC
Greenbelt, MD 20771

National Association of Rocketry
P.O. Box 177
Altoona, WI 54720

Background

There are few things as impressive as watching a space shuttle launch. Even from several miles away, the sun-like flash of the solid rockets as they ignite and the ground-shaking, air-splitting roar as the shuttle rises from the launch pad are overwhelming. But rockets are nothing new. They can be traced back to the first century A.D.

In ancient China, bamboo tubes were crammed with crude gunpowder and then thrown into fires to cause explosions at festivals. Every so often, some of these tubes would shoot out of the fire, causing the revelers to dive for cover. This sparked the interest of local craftsmen who began making fire arrows—the first primitive rockets. By 1232, fire arrows were used in warfare between the Chinese and Mongols.

Several hundred years later, Robert Goddard, an American inventor, achieved the first successful flight with a liquid-propellant rocket on March 16, 1926. Fueled by liquid oxygen and gasoline, the rocket flew for only 2.5 seconds, climbed 12.5 meters, and landed 56 meters away in a cabbage patch. But it was the predecessor of the gigantic Saturn rockets that launched the manned trips to the moon.

A rocket is essentially a chamber that is filled with a gas under pressure and has a small opening that allows the gas to escape. When you inflate a balloon and let it go, you're launching a very simple rocket. The air under pressure provides the thrust that makes the balloon fly.

Newton's Third Law of Motion helps us understand why rockets fly. It states "For every action, there is an equal and opposite reaction." With the balloon, the action is the air under pressure, pushing on the inside of the balloon; the corresponding reaction is the balloon's motion through the air. It's like jumping off a skateboard. You jump in one direction, and the skateboard zips away in the opposite direction.

In the case of a rocket, the gases from burning fuel provide the thrust. Inside the combustion chamber, the exploding gases are pushing upward while gravity pulls the rocket down. If the exploding gases push hard enough, they overcome the weight of the rocket and accelerate it off the launch pad. It takes 3.18 million kg (7 million lbs) of thrust to put the space shuttle into orbit. Each of the two solid rocket boosters provide 1.36 million kg (3 million lbs) of thrust, while the three main engines combine to provide 455,000 kg (1 million lbs) of thrust.

It's important to understand that the rocket does *not* fly because the escaping gases push against the outside air. In the same way the skateboarder's foot pushes against the skateboard, the gases push against the interior of the rocket. In reality, rockets actually work better in the vacuum of space than they do in air!

So, when it comes to physics, there is nothing quite as uplifting as a rocket taking flight!

Video & Stills

Video Segments

Introduction

01:00 to 01:41—Newton's Apple host Dave Huddleston poses some questions about rockets and how they fly. (41 sec.)

Video Clip 1

01:43 to 02:49—Physics expert Jack Netland demonstrates a basic law of physics—where there's action, there's reaction. (1 min. 6 sec.)

Video Clip 2

02:51 to 04:09—With the help of some bean bags, David Heil gets some hands-on experience on how a rocket moves. (1 min. 18 sec.)

Video Clip 3

04:16 to 05:24—Jack Netland demonstrates how a rocket engine produces hot gases which provide the necessary thrust. (1 min. 8 sec.)

Video Clip 4

05:28 to 08:11—Jack Netland points out the large fuel tanks on several model rockets. (2 min. 43 sec.)

Multimedia Resources

Button A

Video: *Newton's Apple* Science Try-It "Water "Turbine" Students can explore action-reaction with a milk carton filled with water. (1 min. 30 sec.)

Button B

Video: NASA footage of several rocket lift-offs. (1 min. 23 sec.)

Button C

Diagram: A simple drawing compares how liquid fuel and solid fuel rockets function.

Button D

Diagram: A drawing illustrates trajectories and orbits.

Unit Assessment Answer Key

The Unit Assessment on the following page covers the basic concepts presented in the video segment and the Background on the Unit Theme section in this guide. The assessment does not require completing all of the activities. However, students should view the complete *Newton's Apple* video before doing this assessment. The Unit Assessment may be used as a pre- or post-test. There is an additional assessment at the end of each activity.

Think about it.

1. The exhaust leaving the rocket exerts a reaction force that causes the rocket to move forward. This is an example of Newton's third law of motion: for every action there is an equal and opposite reaction.
2. Molecules of gas.
3. Vast amounts of fuel are necessary, and fuel tanks take up most of the space of a rocket.
4. Both release molecules of gas, propelling the engine forward.
5. A common example would be when the car you are riding in goes around a curve. You are thrown over to one side or the other because your body wants to continue moving in a straight line.

What would you say?

6. b 7. a 8. b 9. d 10. d

Unit Assessment

What do you know about Rockets?

Write the answers in your journal or on a separate piece of paper.

What do you think?

1. How does a rocket move forward when it is traveling in a vacuum, such as outer space?
2. In the model space shuttle in the video, David Heil—the engine—released bean bags to provide motion. What does a real rocket engine "throw"?
3. Why are rockets so large? What takes up so much space?
4. How is a balloon shooting across a room similar to a rocket engine?
5. Newton's first law of motion states that "an object in motion will stay in uniform motion in a straight line unless it's acted upon by an outside force." Give an example.

What's your choice?

6. When a rocket flies through the air, —
   a. gas molecules are pushing against the air around the rocket.
   b. gas molecules are pushing against inside of the engine of the rocket.
   c. gas molecules are pushing against the Earth.
   d. gas molecules escape as exhaust and do nothing to power a rocket.
7. When a rocket lifts off, which best describes its motion?
   a. The law of action and reaction.
   b. The law of gravity.
   c. Bernoulli's principal.
   d. None of the above.
8. In the video demonstration with the cannon, the cannonball represents —
   a. the rocket.
   b. the fuel of the rocket.
   c. the rocket payload.
   d. Newton's third law.
9. Once a rocket escapes Earth's gravity, —
   a. the rocket's engines do not work any longer.
   b. Newton's third law no longer applies.
   c. fuel is no longer needed.
   d. None of the above.
10. An example of Newton's third law is —
    a. pedaling a bicycle.
    b. swimming.
    c. a gasoline engine.
    d. All of the above.

Activity 1

Newton’s Slider

How does a rocket move? Where does it get its thrust? What is Newton’s third law of motion and how does it apply to a rocket? How does the amount of mass relate to the amount of thrust needed to make a rocket lift off?

Getting Ready

Overview

Students learn how rockets move and why Newton’s third law of motion describes how a rocket flies. Students make a sliding device that propels itself forward by launching projectiles in the opposite direction. Students also learn that increasing the mass of a projectile increases the amount of energy and the forward motion of the device.

Objectives

After completing this activity, students will be able to—

- explain how Newton’s third law of motion applies to the movement of a rocket
- explain the role of mass in controlling a rocket’s thrust

Time Needed

Preparation: approximately 20 minutes
Classroom: approximately 60 minutes

Materials

For the teacher:

- skateboard
- football, softball, or handball

For each group of students:

- a piece of wood approximately 10 cm x 6 cm x 1 cm
- three 1 1/2” roofing nails
- 1 thick rubber band
- an empty 35mm film canister with a lid
- scissors
- 50 pennies
- masking tape
- hammer
- ruler
- spool of thread

Important Terms

kinetic energy—The energy of a moving object.

friction—The resistance to movement caused by the rubbing of two surfaces.

mass—The amount of matter an object has. The greater the mass, the heavier an object is.

potential energy—Stored energy that can be released.

reaction—The force which occurs as a result of a direct action.

Rockets

NEWTON'S APPLE Multimedia

Here's How

Preparation

- Set up the computer to play the CD-ROM (or set up the VCR and cue the tape).
- Make copies of Activity Sheet 1 for each student.
- Gather the necessary materials for the student experiments.
- Review the Background information on page 8.

Video Clip 1
01:43 to 02:49
Physics expert Jack Netland demonstrates a basic law of physics—where there's action, there's reaction. (1 min. 6 sec.)

Video Clip 2
02:51 to 04:09
With the help of some bean bags, David Heil gets some hands-on experience on how a rocket moves. (1 min. 18 sec.)

Engage (Approx. 15 minutes)

Ask the students if they have any ideas about what makes a rocket lift off and what keeps it going. Accept all ideas. (If students indicate rockets must have something to push against, ask how rockets fly in space.) After a brief discussion, explain that the movement of a rocket can be explained by Newton's third law of motion: for every action, there is an equal and opposite reaction.

Show Video Clip 1 [01:43 to 02:49]. Ask students what made the cannon move backward when it was fired? (The cannonball moving forward.) Explain that the exploding gunpowder could only launch the cannonball one way by pushing the other way, inside the cannon. Ask the students to think of how a cannon firing relates to a rocket blasting off. (A rocket and a cannonball are both projectiles.)
Show Video Clip 2 [02:51 to 04:09] David Heil throws bean bags to propel his space shuttle. Ask students how Newton's law is being applied. (action-reaction) Ask them what is pushing a real rocket. Accept all answers.

Have a student volunteer stand on the skateboard facing you. Stand about 5 feet away and ask the student to throw you a baseball. Ask students what pushes the skateboard backward? (The motion of the arm throwing the ball exerts force on the body. On a skateboard, you can get it to move even if you don't let go of the ball!) Now ask the class to predict what will happen when you use a heavier basketball or football. (The skateboard will move farther because the mass of the larger ball is greater, so it takes more muscle force to make it move.) If you throw a ball that's twice as heavy, will the skateboard go twice as far? Maybe four times as far? Does it depend on how hard you throw it? Tell students they are going to explore these questions during this activity.

Guide on the Side

- You may wish to begin the lesson by viewing the Introduction from the Video Menu on the CD-ROM [01:00-01:41]. Find out what students already know about rockets. As a class, discuss the questions posed by Dave Huddleston.
- Students may have difficulty with the idea that a rocket doesn't push "against" anything externally. Accept students' ideas on this and discuss them as part of the activity.
- Remind students to use care when pounding the nails. Follow established classroom safety procedures.
- Nails should not come through the other side of the board.
- To minimize the number of variables, have the students make sure they start the slider from the exact same position each time and that the rubber band is stretched the same distance each time. Students should understand that measurements have to be consistent for them to make valid observations.
- Students may graph the relationship between the number of pennies in the canister and the distance the slider moves. Ask them what their results might mean.
- For best results, rubber band should be adjusted up or down so it is in the middle of the canister's center of mass, depending on the number of pennies.
- If time allows, you may wish to have students view the entire *Newton's Apple* video segment on Rockets.

Activity 1

Explore (Approx. 45 minutes)

Explain that students are going to build a special vehicle to test how changing the mass of a projectile will change the amount of motion. The goal is to use a rubber band to push a mass in one direction. As a result of this action, the device will move in the opposite direction. By measuring the distance that the slider moves when different masses are used, students will observe the relationship between the mass and the amount of motion.

Explain how to construct the sliders. Have students work in small groups. Give each group the materials they will need and a copy of Activity Sheet 1. Have them construct their slider, using the diagram on the activity sheet. They should begin by pounding in the three nails in the positions shown in the diagram.

Take a short length of threads and tie them in equal-size loops. Students can use the film canister as a "template" for the loops. Place the rubber band through a loop of thread and across the two end nails. Pull the rubber band back with the thread, and loop the thread over the third nail. The rubber band should be tightly stretched. Place the film canister in front of the rubber band. Use the scissors to cut the thread so that the rubber band shoots the canister off the back of the slider.

Have students measure the distance the slider moves to determine the relationship between the amount of mass and the distance moved. To increase the mass of the film canister, they add pennies to it, beginning with ten pennies and adding ten more pennies with each successive trial. Students record the results of the trial.

Evaluate

1. What makes the slider move across the table when you release the rubber band? (As the rubber band pushes against the mass, the mass also pushes against the rubber band, which pushes or pulls on the slider. This action/reaction pair makes the slider move forward.)

2. What happens to the distance the slider moves as you increase the amount of mass in the film canister? Why? (The distance should increase because the more mass you push back, the greater the reaction.)

3. How is the Newton's slider similar to a rocket engine? (In a rocket engine, the mass and velocity of the escaping gases cause the action, instead of the rubber band moving the mass.)

Try This

Think about how you might improve the device in this activity to maximize the distance they travel. Hold a competition to see which team can get the most distance out of its vehicle. Besides the mass, is there any other place where the energy can be gained? Would doubling up the rubber band help? How about stretching it farther? Experiment with your ideas.

View the *Newton's Apple* Science Try-It (Resource Button A on the CD-ROM). It contains a short video that explores another application of Newton's third law.

Invent your own action-reaction vehicle using devices such as catapults, slingshots, and springs. Have an "invention convention" to see who can come up with the most unique design using Newton's third law of motion.

Do some research on the development of rocket engines over time and how the fuels they use have changed. What were the first rocket fuels used and what were their limits? Are there any new types of rocket propulsion on the horizon?

Try to make use of Newton's third law in a unique way. For example, have a skateboard race using only projectiles to power your vehicles. Who has a better chance of winning, a heavy person or a light one? What projectiles provide the best thrust? Try it and find out!

Newton's Apple Multimedia

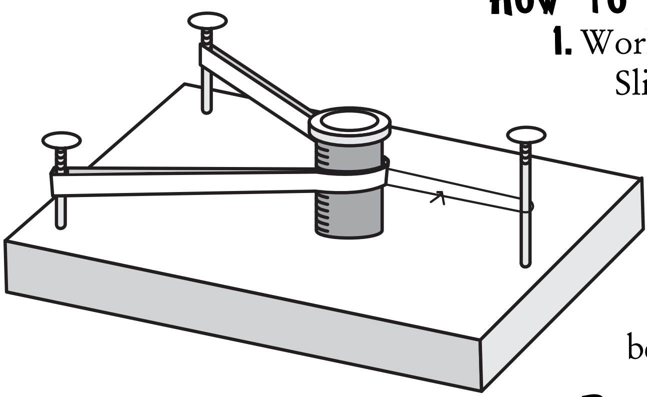
Newton's Slider

Activity Sheet 1

Name ______________________________ **Class Period** ____________

What you're going to do

You're going to build and test a vehicle that moves by using the principles of Newton's third law of motion.



How to do it

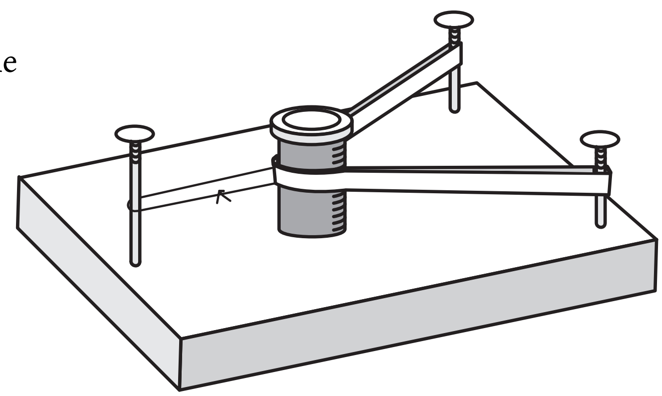
1. Work with a group of classmates and construct a Newton's Slider like the one in the diagram. Test it out a few times using the thread release on the rubber band.
2. Set the slider on a smooth flat surface and mark a starting line with a piece of masking tape. Use the ruler to measure how far the slider travels from the start line each time and record it in the data sheet below.
3. Place pennies in the film canister to increase the mass. Do three trials for each mass and average your results.

Recording your data

In your science journal, set up a data table like the one shown below.

	Distance			
Mass	Trial 1	Trial 2	Trial 3	Average
10 pennies				
20 pennies				
30 pennies				
40 pennies				
50 pennies				

If you have time, graph the results.



What did you find out?

Did the distance the Newton's Slider increase or decrease in a pattern? If so, what was the pattern?

Make a statement that describes the relationship between the distance the Slider traveled and the mass of the projectile.

Predict how far the Slider would move with a mass of 8 pennies. Try it and test your prediction.

Activity 2

Lift Off!

What keeps a rocket on track? Can you steer a rocket? What do fins do for a rocket? Why do rockets have fins in the back and not on the front? How come rockets don't need wings?

Getting Ready

Overview

Students learn how rockets maintain stability in flight. Using a model rocket, they experiment with the position, shape, and size of fins to see how they affect flight.

Objectives

After completing this activity, students will be able to—

- describe how frictional drag affects the flight of a rocket
- explain how fins affect the flight of a rocket

Time Needed

Preparation: 15 minutes
Classroom: 45 minutes

Materials

For the teacher:

- arrow with feathers (fletching) attached
- wooden dowel about 50 mm in diameter and 60 cm long
- large cardboard box

For each group of students:

- pair of scissors
- roll of cellophane tape
- thin plastic drinking straw
- thick plastic drinking straw (should fit snugly over smaller straw)
- 3" x 5" index card

Key Words

drag—In rocketry, the force of moving air against the surface of a rocket.

fin—A device used for deflecting the flow of air over the surface of a rocket.

stability—The tendency to fly in a straight path.

Rockets

Here's How

Preparation
- Set up the computer to play the CD-ROM (or set up the VCR and cue the tape).
- Make copies of Activity Sheet 2 for each student.
- Gather the necessary materials for the student experiments.
- Review the Background information on page 8.

Guide on the Side

- You may wish to begin the lesson by viewing the Introduction from the Video Menu on the CD-ROM [01:00-01:41]. Find out what students already know about rockets. As a class, discuss the questions posed by Dave Huddleston.

- Review classroom safety procedures. Students should not shoot rockets toward another person. You may wish to have students wear eye protection during the activity.

- Tell students that they should test to make sure no air escapes from the rocket nose cone.

- Remind students to try different shaped fins, not only triangular ones.

- If you have many students and a small classroom, you might want to assign each group their own "flight number" so that they can take turns with launches. This will help prevent any "misfires" in the wrong direction.

- If time allows, you may wish to have students view the entire *Newton's Apple* video segment on rockets.

Engage (Approx. 15 min.)

Invite several students to draw quick outlines of rockets on the board. Ask the class what the similarities among the drawings are. Did anyone draw a spherical rocket? Chances are all of the rockets will have conical noses. Ask students why rockets always seem to have the same characteristic shape. Is there anything special about a conical design that makes them fly better? What do all the rockets have in common? (They are all streamlined and have fins. They use engines to produce the power.) You may wish to show the NASA video clip of rocket launches found at Resource Button B on the CD-ROM.

Hold up a wooden dowel in one hand and an arrow in the other. Ask students which will be more stable in flight if they were thrown like darts. Clear an area in front of the class and set a cardboard box on a chair for a target. From a distance of about three meters, (10ft.) throw the dowel and then the arrow into the box. Throw them as if you are throwing a dart. Which had the straighter flight? How is the arrow similar to the rocket?

Explore (Approx. 30 min.)

Tell students they are going to work in small groups to make their own rockets and find out how fins affect the stability of the craft.

Tell students the thick straw will be the body of the rocket. If the straw is the type with an accordion bend in it, have students cut the straw at the bend and use the longer piece. Have them wrap a piece of cellophane tape around the tip of one end of the straw and crimp it tight so that it forms a nose cone. They should blow in the other end of the straw and make sure that no air comes out the taped end. Explain that the narrow straw will serve as the launcher. By slipping it into the rocket body and blowing, the rocket will fly off and across the room. Demonstrate how to launch the rocket and advise students of the proper safety precautions.

Activity 2

Have groups start by testing their rockets with no fins at all. They should record the direction of flight and the overall path. After a few flights, have them modify their rockets with fins cut out of the index card. Suggest that they try placing the fins at different locations on the rocket and also try fins of various sizes. The object is to create a design that will have the smoothest straight flight. After each test flight, have the students record their observations and draw a diagram showing the placement of the fins on the rocket. Advise students that they should test at least three different design modifications.

Evaluate

1. How do the fins on the rocket help improve the stability of the flight? (Air pushes on the sides of the fins, and that pressure tends to keep the fins in a straight line.)

2. What is the best placement for fins on a rocket? (Toward the tail of the rocket; students may have other observations as well.)

3. What is the purpose of having a nose cone on a rocket and why are rockets streamlined? (The streamlined shape and nose cone help to cut down on drag or air resistance.)

4. Once a rocket is in space, would the fins help or hurt the flight? Explain. (Neither. In space there is no air so the fins have no effect on flight.)

Try This

How would changing the weight of the rocket affect its flight? Try modifying your rocket by placing bands of tape at different locations on the body. Do heavier rockets fly better than light ones?

After experimenting with straw rockets of different designs, have a trajectory contest. Set up a “firing range” in an open area of the classroom and use either a garbage can or a large ring as the “splash down” point. See what design can make the most accurate landings.

Research the history of launch vehicles and discover some of the criteria that NASA and Jet Propulsion Lab engineers use in selecting rocket types for various missions.

NEWTON'S APPLE Multimedia

LIFT OFF!

Activity Sheet 2

NAME ______________________________ CLASS PERIOD __________

WHAT YOU'RE GOING TO DO

You're going to make soda-straw rockets and investigate how fins on a rocket affect its flight.

HOW TO DO IT

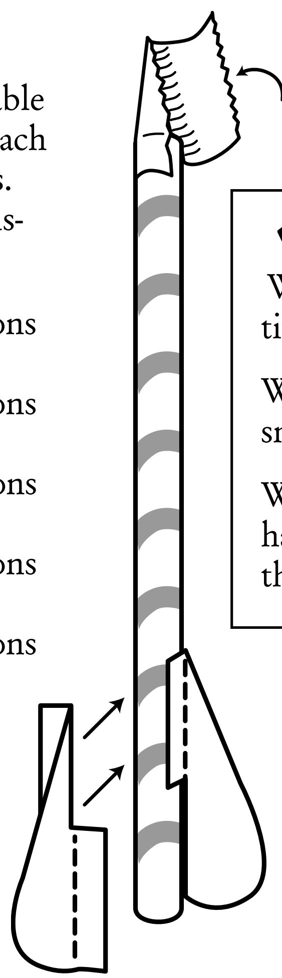
1. Follow the diagram. Make the basic rocket by forming a nose cone out of tape and attaching it to the thicker straw. Make sure that the nose cone doesn't let air escape. Do not attach fins to the rocket. Test the flight of the finless rocket a few times and record your observations.

2. Cut out fins from the file card and attach them to the straw rocket body using cellophane tape. Draw a sketch of how your rocket and fins look and then test the rocket. Record your observations next to the drawing. Change the design of your rocket by either moving the fins or trying a new fin design. Each time you adjust the design, draw a sketch and then test it. Be sure to record your observations of the flight.

RECORDING YOUR DATA

In your science journal, create a data table like the one shown. Draw a sketch of each design. Then record your observations. Include information about stability, distance, and trajectory.

Rocket without fins	Observations
First design	Observations
Second design	Observations
Third design	Observations
Fourth design	Observations



WHAT DID YOU FIND OUT?

Where on a rocket are fins most effective?

What other modifications might create a smoother flight?

Which design worked best? What might have made this design work better than the others?

Activity 3

Rocket Power

How does Newton's third law of motion apply to rocket engines? How do expanding gases provide the necessary thrust to propel a rocket? How does a rocket-powered vehicle work?

Getting Ready

Overview

Students learn how a rocket engine works. They discover how expanding gases are used to propel a rocket through space. Students use a balloon to build and test their own "rocket-powered" racer.

Objectives

After completing this activity, students will be able to —

- explain how Newton's third law of motion applies to rocket engines
- discuss variables that alter the efficiency of a rocket-powered vehicle

Time Needed

Preparation: approximately 20 minutes
Classroom: approximately 50 minutes

Materials

For the teacher:

- large balloon

For each group of students:

- 9" balloon
- 2 rectangular pieces of corrugated cardboard 40 cm x 12 cm
- strong pair of scissors (for cutting cardboard)
- 2 plastic drinking straws
- 2 small wooden shish kebab skewers
- roll of cellophane tape
- 8 small rubber bands
- the plastic lid from a 1 lb. coffee can or other circular templates for wheels
- bottle of white glue
- metric ruler

Key Words

inertia—The tendency for an object to remain at rest or in motion. The greater the mass, the greater the inertia.

propel—To push or move in a straight line.

NEWTON'S APPLE Multimedia

Rockets

Here's How

Video Clip 3
04:16 to 05:24
Jack Netland demonstrates how a rocket engine produces hot gases that provide the thrust for the rocket. (1 min. 8 sec.)

Video Clip 4
05:28 to 08:11
Jack Netland points out the large fuel tanks on several scale model rockets. (2 min. 43 sec.)

Preparation

- Set up the computer to play the CD-ROM (or set up the VCR and cue the tape).
- Make copies of Activity Sheet 3 for each student.
- Gather the necessary materials for the student experiments.
- Review the Background information on page 8.

Engage (Approx. 10 min.)

Begin by blowing up a balloon. Pinch the end closed with your fingers. Release the balloon and let it fly around the room. Based on their observations, ask students to explain what made the balloon fly. (When the balloon is still sealed, all of the forces inside the balloon balance each other, and the balloon doesn't move. i.e. the skin of the balloon pushes on the air and the air pushes on the skin of the balloon. When you release air out the mouth of the balloon, the air is still pushing on the inside of the front, but now, at the mouth, there's no resistance to the air.) Based on their knowledge of Newton's third law of motion, ask students to explain what provided the action and reaction. (The air moving out of the balloon was the action; the balloon being pushed forward by the air was the reaction.) Ask the students to think about how the motion of the balloon is similar to the way a rocket works.

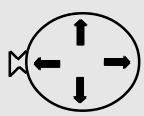
Show Video Clip 3 [04:16 to 05:24]. Do the students notice anything peculiar about the balloons? (The red balloon with hydrogen is almost used up while the blue balloon with oxygen is still half full.) What does this demonstrate? (When a rocket engine fires, it doesn't use the fuel evenly.)

Why is so much fuel needed in the Saturn V to get such a small capsule to lift off? (The amount of mass that the rocket has with a full load of fuel makes it tough to escape Earth's gravity.) Why does a rocket first lift off slowly and then start to speed up? (Due to inertia, movement starts slowly and then speeds up.)

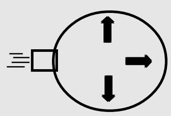
Show Video Clip 4 [05:28 to 08:11]. The segment ends with some fascinating facts about rockets. Ask the students to explain how the fire extinguisher powers David's tricycle. (Gasses from the fire extinguisher pass out of the nozzle in one direction, so the extinguisher and cart move in the opposite direction—Newton's third law.) Explain that when we see the rush of gases from a rocket, we tend to think there's "something happening" there. In fact, we're only seeing the "leftovers." The gases that are really doing the work are inside the rocket, where we can't see them.

Guide on the Side

- The forces on the inside of the balloon:



Balloon Sealed. All the forces balance.



Balloon Released. At the mouth, there's no longer force ON the balloon at that point. So the sum of all the forces results in a big push on the front of the balloon.

- Tracing coffee can lids creates fairly large wheels. A simple compass may also be used to draw the circle for the wheels. Students may want to experiment with different sized wheels.
- Thin styrofoam can be substituted for cardboard in the activity. The styrofoam trays for packaging meat work well. Be sure they are thoroughly cleaned!
- The axle should go through the exact center of the wheel. Direct students to be careful in determining the center of the wheel.
- A small dab of hot melt glue works well to secure the wheels to the axles.
- If vehicles are not moving in a straight path, the axles are not parallel and should be remounted.
- One of the key energy losses in the vehicle is due to friction. Have the students evaluate places where friction could be hurting the performance of their vehicles.
- If time allows, you may wish to have students view the entire *Newton's Apple* video segment on rockets.

Activity 3

Explore (approximately 40 minutes)

Have students work in groups to design and build a balloon-powered rocket racer. The object is to build a vehicle that will achieve the greatest distance. The basic design is shown on the activity sheet, although students should be encouraged to modify this design.

Have students use the coffee can lid to trace four wheels on a piece of cardboard. They should cut out the wheels and make sure that the wheel edges are as smooth and round as possible. Next, have students punch a small hole in the exact center of each wheel.

Have students take the second piece of cardboard and mark a line across the short side about 10 cm (4 in.) from one end. Carefully fold the cardboard along the line and put a hole about 4mm (1/4 in.) wide through the center of the small folded section. The balloon will go in this hole.

Have students use cellophane tape to attach the two straws across the width of the larger section of the folded cardboard. The straws must be parallel to each other and should be at least 20 cm (8 in.) apart. Students should place shish kebab skewers through the straws to serve as axles. Wheels should be attached to each axle. The wheels should turn smoothly without rubbing on the frame of the vehicle.

Insert the balloon through the hole at the back of the car so that the nozzle of the balloon is facing out the back. Blow up the balloon while it's attached to the car and pinch the end closed. Place the vehicle on a smooth floor and release the balloon. The car should start to roll across the floor under it's own power. Students should test the vehicle and make modifications to maximize the car's distance. They should keep a record of the modifications and the results in performance.

Evaluate

1. Why does the rocket-powered racer start slowly and then speed up as it moves across the floor? (It takes a great deal of energy to overcome the initial inertia, but once it starts moving, it starts to develop some momentum.)

2. In this particular vehicle, explain how the car is being powered by the air escaping from the balloon. (The air escaping from the balloon is actually pushing against the balloon itself. Since the balloon is attached to the car, the car moves with it.)

3. How would increasing the mass of the car affect its overall performance? Why? (Increasing the mass would give the car more inertia which would mean that it would take longer to get going and probably wouldn't go as far.)

Try This

Rocket power is not new in the animal kingdom. Creatures like the squid and octopus use the principle of rocket propulsion to move around their environments. Research animal propulsion and find out how these creatures have used Newton's laws to adapt to their environments. What other features besides propulsion do they share with modern rockets?

Research how rocket cars actually work. What can you find out about rocket-powered cars and boats? What are the record speeds for rocket cars and boats. Report your findings to the class.

Explore how to construct water rockets. Search the Internet or find information in the library. Build rockets, then stage a rocket festival. Hold contests for the rocket that flies the highest, has the most interesting design, etc.

NEWTON'S APPLE Multimedia

Rocket Power

Activity Sheet 3

Name ______________________________ **ClassPeriod** ____________

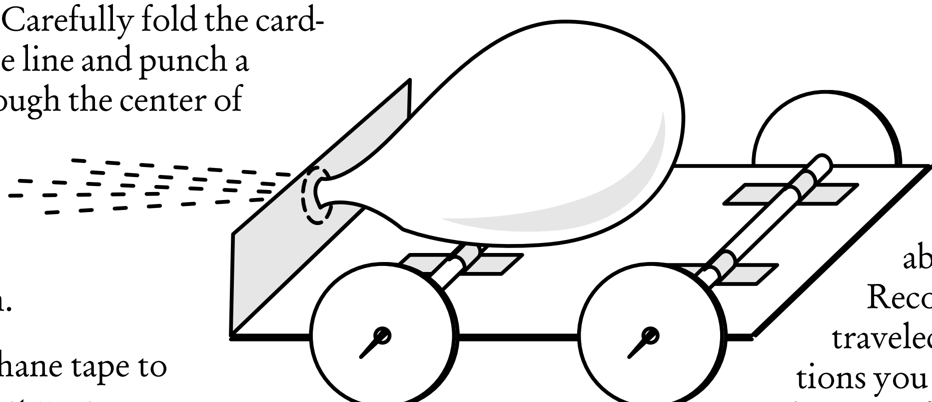
What you're going to do

You're going to build and test a vehicle that uses a balloon to provide rocket power.

How to do it

1. Use the diagram to help you build your racer. Trace the outline of a coffee can lid on a piece of cardboard and cut out four wheels. Make sure that the wheel edges are as smooth and round as possible. Punch a small hole in the exact center of each wheel.

2. Mark a line across the width of the second piece of cardboard about 10 cm from one end. Carefully fold the cardboard along the line and punch a small hole through the center of the small folded section. This hole will be for the balloon.



3. Use cellophane tape to attach the two straws across the width of the larger section of the folded cardboard. The straws must be parallel to each other and at least 20 cm apart. Place one shish kebab skewer through each straw to serve as an axle and attach a wheel to each axle. You can also use a tightly wrapped rubber band around the end of the axle to secure the wheels or you can glue them in place.

4. Insert the balloon through the hole at the back of the car so that the nozzle of the balloon is facing out the back. Blow up the balloon while it's attached to the car and pinch the end closed. Place the vehicle on a smooth floor and release the balloon. The car should start to roll across the floor under its own power. After a few trials, try to maximize your car's distance by making modifications. Record the modifications you make.

Recording your data

In your science journal, record information about each design. Record the distance traveled and any observations you have made. Draw a diagram of each modification you make to your rocket car. Indicate if the modification helped the car or not.

What did you find out?

What factors made a difference in the distance your team's rocket car traveled?

What modifications could you make that would improve performance?

How did your team's car perform compared to others in the class? What might account for the differences?

NEWTON'S APPLE. Multimedia

Gravity Teacher's Guide

Down to Earth

What is gravity? Does gravity affect large and small objects in the same way? Is there gravity in outer space? Are astronauts really weightless?

Themes and Concepts

- gravity and weightlessness
- acceleration and velocity
- the path of a projectile
- orbits and orbiting

National Science Education Standards

Content Standard A: Students should develop abilities necessary to do scientific inquiry.
Content Standard B: Students should develop an understanding of motions and forces.
Content Standard G: Students should develop an understanding of the nature of science.

Activities

1. Falling and Falling—approx. 20 min. prep; 60 min. class time
How does an object orbiting the earth experience weightlessness? Are astronauts in orbit truly weightless? Students investigate why objects appear to be weightless in free fall by simulating the free fall of an orbiting body in three ways.

2. Around and Around—approx. 30 min. prep; 75 min. class time
How does an object stay in orbit around the earth? How do the horizontal and vertical components of a projectile's motion affect one another? Students simulate the movement of a projectile and investigate its motion.

3. Faster and Faster—Approx. 30 min. prep; 45 min. class time
What is acceleration and velocity? What determines the acceleration of a falling object? Is acceleration constant? Does velocity affect the acceleration of a falling object? Students investigate the roles of acceleration and velocity in falling objects.

More Information

Internet

Newton's Apple
http://www.ktca.org/newtons
(The official *Newton's Apple* web site with information about the show and a searchable database of science ideas and activities.)

NASA Spacelink
http:/spacelink.msfc.nasa.gov
(An educational site for NASA with references, activities, and links dealing with many aspects of space flight and gravity.)

Gravity Questions Answered — University of Maryland
http:/www.physics.umd.edu/rgroups/gen_rel_the/question.html
(An interactive web site that allows teachers and students to pose questions about gravity that are answered by the physics faculty of the University of Maryland.)

Internet Search Words
gravity, microgravity, weightlessness, satellites

Books and Articles
Crummett, B. “Measurements of the Acceleration Due to Gravity.” The Physics Teacher. (May, 1990):p. 291.

Eckroth, C. “Earth and Moon Motions Around Their Common Center of Mass.” *The Physics Teacher*. (September, 1990)

VanCleave, Janice. Gravity: Mind-Boggling Experiments You Can Turn Into Science Fair Projects. New York: John Wiley & Sons, 1993. (Excellent, simple, hands-on activities)

Boslough, J. “Searching for the Secrets of Gravity.” *National Geographic*. (May, 1989): pp. 563-583.

Epstein, L. *Thinking Physics*. San Francisco: Insight Press, 1989.

“Overcoming the Human Factor (cosmonauts deal with problems living in space).“. *U.S. News and World Report*. (May 16, 1988).

Community Resources
NASA Educational Outreach
Lewis Research Center
Cleveland, Ohio 44135

Physics and astronomy departments at local colleges or universities

Local skydiving clubs

Background

What is it that keeps us from floating up into the sky when we step outside? What force keeps Earth orbiting the sun instead of spinning off into space? Isaac Newton contemplated these questions in 1666 and came up with his “universal law of gravitation.” Today, well over 300 years later, Newton’s concept of gravity is still universally accepted by scientists.

We tend to think of gravity as the pull of the earth on our bodies—what we feel as our weight. That’s correct, but gravity is more than that. It’s also the force that *we* exert on the earth. Gravity is the attraction between any two objects that have mass — between the sun and other stars, between tiny molecules, or between you and Earth. The size of the force is proportional to the mass of the object, so we exert a much, much smaller force on Earth than the Earth does on us.

Newton’s profound insight (as he supposedly watched an apple fall from a tree) was how the force of gravity operates the same way, everywhere in the universe. At Earth’s surface, gravitational force makes falling objects accelerate at a fixed rate of 9.8 meters per second for every second they fall. If a falling rock were somehow equipped with a speedometer, in each succeeding second of the fall its reading would increase by 9.8 meters per second.

The force of gravity does decrease with distance: The farther apart objects are, the smaller the force of gravity is between them, but it never vanishes completely. And for very large objects, like stars and planets, the force of gravity is still strong over great distances. For example, the sun’s gravity keeps Earth in orbit, and the sun is 93 million miles away!

When you see pictures of astronauts floating in an orbiting spacecraft, it’s tempting to think that they are far enough from the earth that they are totally weightless. (If there were no gravity out in Earth orbit and beyond, then the moon would drift off into space!) The astronauts are inside a spacecraft orbiting Earth at several thousand miles an hour. It is their speed and acceleration relative to the shuttle that gives them the experience of weightlessness. The force of gravity doesn’t vanish, it’s simply canceled out by the motion of the spacecraft.

When Soviet cosmonaut Oleg Atkov came back to Earth in 1988 after eight months in the space station Salyut 7, he was so weak he had to be carried from his landing craft. The physical problems suffered by Atkov were blamed on the weightless environment. Our bodies are adapted to Earth’s gravity. When that gravity is canceled out in an orbiting spacecraft, muscles begin to atrophy and bones begin to weaken. Our very existence, including muscle tone, body shape, and bone strength, is governed by gravity.

It may be fun to float in space, but scientists believe that for very long space flights to places like Mars, spaceships will have to have some form of artificial gravity. And maybe a bumper sticker that reads, “Gravity   don’t leave home without it!”

Video & Stills

Video Segments

Introduction

8:26 to 9:23—Eileen Galindo poses questions about gravity and introduces host David Heil and physics expert Jack Netland.

Video Clip 1

9:24 to 10:26—David Heil and Jack Netland observe the effect of gravity on a container of water in free fall. (1 min. 2 sec.)

Video Clip 2

11:44 to 12:50—Jack Netland explains an everyday experience of weightlessness—a dropping elevator. (1 min. 6 sec.)

Video Clip 3

12:55 to 16:02—David Heil and Jack Netland explore the force of gravity on projectiles and orbiting spacecraft. (3 min. 7 sec.)

Video Clip 4

16:07 to 18:19—David Heil solves the classic "Monkey and Hunter" riddle. (2 min. 12 sec.)

Multimedia Resources

Button A

Video: *Newton's Apple* Science Try-It "Projectiles and Satellites." Students can explore how projectiles work. (55 sec.)

Button B

Video: Astronaut Jeff Hoffman explains free fall in orbit. (31 sec.)

Button C

Video: Astronaut juggling apples in the space shuttle. (29 sec.)

Button D

Diagram: A series of pictures demonstrate how a dropping elevator can cause weightlessness.

Answer Key to Unit Assessment

The Unit Assessment on the following page covers the basic concepts presented in the *Newton's Apple* video segment and the overview section in this guide. The assessment does not require completing all of the activities. The Unit Assessment may be used as a pre- or post-test. However, students should view the complete *Newton's Apple* segment on the CD-ROM or videotape before doing this assessment. There is additional assessment at the end of each activity.

Think about it.

1. Air resistance causes friction that decreases acceleration.
2. 10 meters per second.
3. Answers will vary. A feather, a sheet of paper, and a tissue would be affected by air resistance; a bowling ball, a rock, and a baseball would not be affected significantly.
4. Directly above the flare.
5. It means five times the pull of gravity and makes the astronauts feel five times heavier.

What would you say?

6. a 7. c 8. b 9. d

NEWTON'S APPLE Multimedia

Unit Assessment

What do you know about Gravity?

Write the answers in your journal or on a separate piece of paper.

Think about it.

1. What is the effect of air on the acceleration of a falling object?

2. If you throw a ball straight up with a speed of 10 meters per second, how fast will it be moving when you catch it?

3. List three examples of falling objects for which air resistance greatly affects the object's acceleration. What are three examples of falling objects for which air resistance is not an important factor?

4. An airplane pilot is flying at a constant velocity and constant altitude over level ground. The pilot drops a flare. Ignoring air resistance, where will the plane be relative to the flare when the flare hits the ground?

5. During space flight, astronauts often refer to forces as multiples of the force of gravity on the surface of the Earth. What does the force of 5 g mean to an astronaut?

What would you say?

6. A glass of water falls off the ledge of a fifth-floor window. Just as it passes the third-floor window someone accidentally drops a flower pot from the window. Which of the following statements is true?
   a. The glass of water hits the ground first and with higher speed than the flower pot.
   b. The flowerpot hits the ground at the same time as the glass of water, but the speed of the flowerpot is greater.
   c. The flowerpot and the glass hit the ground at the same instant and with the same speed.
   d. The flower pot hits the ground before the glass.

7. Ignoring air resistance, if a 10-kg ball and a 200-kg crate were both dropped from the top of a building, the acceleration of the crate would be ____ the acceleration of the ball.
   a. two percent more than
   b. less than
   c. equal to
   d. twenty time

8. A toy rocket is launched straight up into the air. When the rocket reaches its maximum height, its velocity is—
   a. at its minimum.
   b. zero.
   c. equal to its displacement multiplied by time.
   d. equal to its displacement divided by its time.

9. You throw a ball horizontally as hard as you can. At the same instant, your friend drops a ball from the same height as you throw. What happens?
   a. Your friend's ball will land first.
   b. Your ball will land first.
   c. Gravity won't affect the thrown ball.
   d. They will both hit the ground at the same time.

Activity 1

Falling and Falling

Are astronauts in orbit really weightless? Does weightlessness mean there's no gravity? Can you experience weightlessness on Earth? How does a satellite or space shuttle move through space? Do orbiting objects really fall toward the Earth?

Getting Ready

Overview

Students simulate weightlessness in three ways and explore why an object seems weightless when it is actually in free fall toward the Earth.

Objectives

After completing this activity, students will be able to—

- explain free fall for objects orbiting Earth
- explain the role of horizontal velocity for objects orbiting the Earth
- describe the relationship of a body's weight and movement

Time Needed

Preparation: Approx. 20 min.
Classroom: Approx. 60 min.

Materials

For each group of students:

- empty 16 oz. can
- 2 rubber bands
- nail and small hammer
- masking tape
- 5-gallon pail
- an 8-ounce Styrofoam cup
- food coloring and water
- 20-Newton spring scale
- kilogram weight, such as an exercise weight or a lump of clay
- newspaper
- several heavy metal washers

Important Terms

gravity—One of four natural forces. The force of attraction between two or more objects that have mass; the force of the Earth's mass on bodies on or near the Earth.

acceleration—The rate of change of velocity, expressed as meters per second per second (m/s^2)

velocity—A measurement that expresses both the speed and direction an object is moving.

Gravity

Here's How

Video Clip 1
09:24 to 10:26
David Heil and Jack Netland observe the effect of gravity on a container of water in free fall. (1 min. 2 sec.)

Video Clip 2
11:44 to 12:50
Jack Netland explains an everyday experience of weightlessness—a dropping elevator
(1 min. 6 sec.)

Guide on the Side

- You may wish to begin the lesson by viewing the Introduction from the Video Menu on the CD-ROM [08:26-09:23]. Find out what students already know about gravity. As a class, discuss the questions posed by Eileen Galindo.
- If a video camera is available, it is very helpful to videotape the falling objects for observation in these activities. For best results, the camera should tilt and follow the object down rather than remaining stationary. The image will be less blurred when replaying in slow motion or freeze frame.
- The concept of weightlessness is difficult for many people to understand. Many students believe gravity doesn't exist in space. Allow time to discuss this concept to help students understand it.
- It may be more convenient to mix a large quantity of colored water in advance of the activity than to have students do it at their desks. The colored water can then be distributed to student groups.
- Colored water can stain clothing. Students may wish to wear lab aprons for that portion of the activity.
- You may wish to prepare cans with the hole in the bottom in advance. It may help the activity to go more smoothly. It also insures that the holes are centered and not too large.
- When the washers are attached to the rubber bands in the soup can, the rubber bands should have a bit of tension in them. Choose the size of rubber band accordingly. You may use coins, 20 gram masses, or other weights to achieve similar results.
- If time allows, you may wish to have students view the entire *Newton's Apple* video segment on gravity.

Preparation

- Set up the computer to play the CD-ROM (or set up the VCR and cue the tape).
- Gather the necessary materials for the student experiments.
- Make copies of Activity Sheet 1 for each student.
- Review the Background information on page 24.

Engage (Approx. 15 min.)

Everyone has probably seen an astronaut on television in a weightless environment. Ask students what they think it would be like to be weightless in orbit around Earth. Accept all answers.

Ask the students what causes weightlessness. Accept all answers. Show Video Clip 1 [09:24 to 10:26]. Ask students what happened to the water that was leaking out the bottom of the container. (It stopped leaking.) Ask them why the water stopped leaking when the container was dropping. (Because the container and water were accelerating at the same rate.)

What is weightlessness? (It is the sensation of falling.) Tell the students that they have all probably experienced weightlessness at one time or another. Ask them if they can think of examples. Tell students that they experience weightlessness when they jump off a diving board. Explain that when you are on a rapidly falling elevator, you experience a weight reduction that will show up on a scale.

Show Video Clip 2 [11:44 to 12:50]. Ask students how a falling elevator is similar to an object that is in orbit around Earth. (Both objects are falling toward Earth.) Ask them what would happen if you held your keys out in front of you and let go of them while jumping from a high board at a pool. (Everything would fall at the same speed, so the keys would appear to float in front of you.) Resource Button B on the CD-ROM has an additional video clip that discusses weightlessness.

Explore (Approx. 45 min)

Tell the students they are going to explore the phenomenon of gravity in three ways.

Part 1: Styrofoam Cup and Colored Water
Have students use a nail to make a hole through the side of the Styrofoam cup. The hole should be on the side, near the bottom. Have them cover the hole with a finger and fill the cup with colored water. Next, tell students to remove their finger and allow the water to flow into the 5-gallon pail. Have students observe the stream and record their observations in their journals. (Water streams out in an arc.)

Activity 1

Tell students to refill the cup, release their finger from over the hole, and drop the cup, at the same time into the pail from about 2 meters. Before they drop the cup have them write a prediction of what will happen. Then have students observe the stream of water as the cup falls into the pail and record their observations. (The stream will either not start or stop soon after the cup begins to fall.)

Part 2: Soup Can and Washers
Have students work in groups. Tell students to make a small hole with the nail in the middle of the bottom of the soup can. Have them make one cut in each rubber band, and then push one ends of each rubber band through the hole in the can. Tie ends of the bands in a knot on the outside of the can and secure the knot with tape. Then tie one washer to each free end of the connected rubber bands. Finally, hang the washers over the edge of the cup. The rubber bands should be under slight tension.

Tell students they're going to drop the cup into the five-gallon pail from a height of about two meters. They should write a prediction of what they think will happen and then observe what happens when they drop the cup. They should write a description and explanation of their observations. (In free fall, the tension in the rubber bands pulls the "weightless" washers into the cup as the rubber bands return to their unstretched length.)

Part 3: Spring Scale and Mass
Have students loosely crumple several sheets of newspaper and put them in the bottom of the 5-gallon pail. Tell them to attach a 1kg weight to the hook of a 20-Newton spring scale. Have the students hold the top of the scale and measure and record the weight. Next, tell students they will hold the scale about 2 meters above the pail, and then release the scale and let it fall into pail. Before performing the activity, students should make predictions. They should then carefully observe and record the weight indicated as the scale falls into the pail. (The weight should be significantly lower than 1 kg.)

Evaluate

1. When you drive rapidly on a hilly road or ride on a roller coaster, you feel lighter as you go over low hills and heavier as you reach the bottom of a hill. Explain why this is so. (The acceleration that the rider experiences changes as the car and its occupants move up and down relative to the Earth. The body is sensitive to these changes in acceleration and senses them as weight changes.)

2. Suppose you were going to work in a "weightless" environment of space. How would you have to modify your everyday activities to accommodate your new environment? (Answers will vary. Students should indicate that most tasks would be very different. Accommodations would have to be made for virtually every activity from washing dishes to throwing a ball. A person could not use his/her weight to their advantage.)

3. What statement could you make about gravity based on your observations in these three experiments? (Answers will vary. When two objects are falling, they tend to fall at the same rate of speed or accelerate relative to one another. Objects become "weightless" during their fall.)

Try This

Have a representative from a sky diving club come to your class and speak about free falling and weightlessness.

Research Galileo's classic experiments with gravity and falling objects. Students may want to replicate these experiments for the class.

Write or e-mail NASA (see resources) and request two items: a "Mission Highlights" for a recent space shuttle flight and a "Groundtrack Chart" for the same mission. Use these two items to list the purpose and accomplishments of a shuttle mission and chart the orbital paths that the shuttle covered.

FALLING & FALLING

Activity Sheet 1

NAME ______________________ **CLASS PERIOD** __________

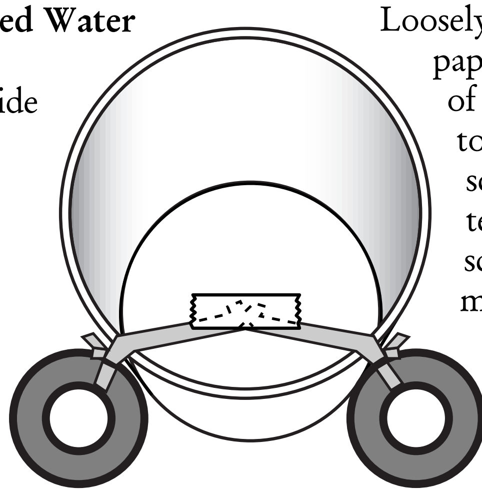
WHAT YOU'RE GOING TO DO

You're going to investigate free fall and the concept of weightlessness.

HOW TO DO IT

1. Styrofoam Cup and Colored Water

Work with your group. With a nail, punch a hole through the side of the cup near the bottom. Put your finger over the hole and fill the cup with colored water. Remove your finger and allow the water to pour into the pail. Record your observations in your journal. Refill the cup. With the cup held over the pail, you will release your finger from the hole and drop the cup into the pail at the same time. Predict what will happen and write your prediction in your journal. Carefully observe the cup and water fall into the pail. Record your observations in your journal. How did your observation compare to your prediction?



2. Tin Can and Washers

Work with a team. Follow your teacher's directions and refer to the diagram when building the device for this activity. After the device is constructed, hang the washers over the edge of the can. The rubber bands should be under some tension. You are going to drop the can into the five-gallon pail from a height of about 2 meters. Predict what will happen, then perform the activity. Record your observations in your journal. Try this several more times and record any differences you may observe. How did your prediction compare to your observations?

3. Spring scale and mass

Loosely crumple several sheets of newspaper and put them on the bottom of the pail. Attach the 1 kg weight to the hook of a 20-Newton spring scale. Record the weight registered. You will be dropping the scale and weight from about 2 meters above the pail. Predict what will happen. Record your prediction in your journal. Now drop the scale and weight from about 2 meters above the pail. Carefully observe the weight on the scale as it falls. Repeat if necessary to obtain a good reading. Record this information.

RECORDING YOUR DATA

Set up a data table in your journal and record your predictions and observations.

WHAT DID YOU FIND OUT?

Explain why the draining water acted as it did in this investigation.
Explain why the washers acted as they did in this investigation.
Explain any differences between your predictions and your observations.
Compare your results and observations to those of other groups. What might account for any differences?

Activity 2

Around and Around

What is a projectile? What effect does gravity have on a projectile? Does gravity affect objects that are orbiting Earth? If you were orbiting 200 miles above the surface of Earth and threw a ball straight out in front of you, how would it move?

Getting Ready

Overview

Students launch a steel ball on an inclined board and observe the path of the ball as it falls in an orbiting motion. As the horizontal launching velocity is changed, the ball takes different paths that students study and compare. The activity stresses the connection between a projectile and an object in orbit.

Objectives

After completing this activity, students will be able to—

- explain the concept of projectile motion
- explain the independence of the horizontal and vertical motions of a projectile
- discuss the motion of a projectile and relate it to that of an orbiting object

Time Needed

Preparation: Approx. 30 min.
Classroom: Approx. 75 min.

Materials

For each group of students:

- steel ball (approx. 2.5-3.0 cm diameter)
- sheet of graph paper
- masking tape
- 30 cm x 30 cm board or similar portable flat wood surface
- metric ruler with groove in the center
- sheet of carbon paper
- books for elevating the plane and the ruler

Important Terms

air resistance—The frictional force of air against moving objects.

height of fall—The height from which a projectile drops.

trajectory—The curved path or arc that a projectile follows as it moves through space.

friction—A force between surfaces or substances that resists the motion of one object or surface past another.

Gravity

Here's How

Preparation

- Set up the computer to play the CD-ROM (or set up the VCR and cue the tape).
- Gather the necessary materials for the student experiments.
- Make copies of Activity Sheet 2 for each student.
- Review the Background information on page 24.

Engage (Approx. 15 min.)

Ask students what a projectile is and to give examples. List their suggestions on the board. (missile, bullet, a snowball in the air, a toy car that rolls off a table) Ask what these things have in common. Try to elicit that a projectile is an object that is projected forward and follows an arc-shaped path as it moves. Can an orbiting object be considered a projectile? (Yes.) Do projectiles follow predictable paths? (Yes.)

Show Video Clip 3 [12:55 to 16:02]. Ask students how it's possible for both balls to land at the same time. (Gravity affects falling objects in the same way.) Ask students how the object launched horizontally is similar to an orbiting object. (They both follow the path of a projectile perpendicular to the pull of gravity.)

Discuss the concept of projectiles with the class. Have your students imagine Earth without gravity. What would happen if they threw a ball straight out in front of them? (It would continue moving in the same direction [a straight line] forever—or until it hit something.) What would happen if they dropped the same ball in the presence of gravity? (The same ball would fall toward Earth with an increasing velocity.) Explain that the path of a projectile is the combination of these two motions—forward and downward.

Explore (Approx. 60 min.)

Have students work in small groups. Explain that they are going to simulate, observe, and record the motion of a projectile. Explain that the projectile is a steel ball that they will release on an inclined plane. By rolling balls down a ramp, you can actually see the effect of gravity. (This is how Galileo made his discoveries in the 1600s.)

Have students construct the testing apparatus. They should refer to the illustration on the activity sheet. Have them test the apparatus to make sure it functions correctly. The ball should roll from the chute and curve across the paper. Then attach the paper with the carbon paper on the outside, facing the blank sheet.

Tell students to launch the projectile three times from different points on the ruler, at least 5 cm apart. The launch points result in different launch velocities. This will create three projectile paths on the graph paper.

After students have launched the steel ball from three heights on the ruler, have them remove the carbon paper and retrace the paths on the graph paper with a pencil to make them darker. Next, have them draw a horizontal line across the paper at the launch height. They then divide the space from that line to the bottom of paper into 10 equal parts by drawing a series of parallel horizontal lines. These represent the horizontal distances the projectiles traveled. Students should label these intervals A through J.

Video Clip 3

12:55 to 16:02—David Heil and Jack Netland explore the force of gravity on projectiles and orbiting spacecraft. (3 min. 7 sec.)

Guide on the Side

- You may wish to begin the lesson by viewing the Introduction from the Video Menu on the CD-ROM [08:26-09:23]. Find out what students already know about rockets. As a class, discuss the questions posed by Eileen Galindo.
- The apparatus set-up may be confusing to students. You may wish to build one before class so that students can see what it is supposed to look like when completed. Direct them to follow the diagram on Activity Sheet 2.
- Hot melt glue is a good way to attach the launcher to the board. Students should follow established safety pro-cedures if they use hot glue.
- It is important to use a heavy steel ball as a projectile. A heavier ball makes a darker impression with the carbon paper. You can find large steel ball bearings at many hardware or auto parts stores. The ball from a pinball machine works well.
- Fresh carbon paper works best.
- You may choose to vary the angle of the inclined plane. This would introduce another variable. To do this, have students prop up their ramp at a greater angle.
- It should be emphasized that the friction is so small that the horizontal velocity is constant over the short distance that the ball rolls.
- Many good computer graphing programs are available if you have access to a computer lab. The two graphing exercises that accompany this lab might be a good opportunity to use one of these.
- If time allows, you may wish to have students view the entire *Newton's Apple* video segment on gravity.

Activity 2

Tell the students to divide the longest projectile path into ten equal segments with vertical lines beginning at the launching point. These sections represent time intervals. Have students label the time intervals 1 through 10. The speed of the projectile doesn't change; it goes the same distance in each interval of time. For each of the ten intervals, have students measure the vertical distance from the launch height to the projectile path for each of the three projectile paths.

The table for one path might look like this:

Path One—vertical distance

vertical segment	1	2	3	4	5	6	7	8	9	10
distance to path	2cm	3cm	4.5cm	7cm	11cm					

One table for horizontal distance might look like this:

Path One—horizontal distance

vertical segment	1	2	3	4	5	6	7	8	9	10
horizontal distance	2cm	2cm	2cm	2cm	2cm					

Determine the distance the ball traveled down the ramp for each time interval. Subtract the distance the ball "falls" in one interval from the one before it. How far does the ball "fall" in one interval of time compared to the previous one? More or less? Is it speeding up or slowing down? The table for increases in vertical distance might look like this:

Path One—increase in velocity

vertical segment	1	2	3	4	5	6	7	8	9	10
increase	0cm	1cm	1.5cm	2.5cm	4cm					

Next, tell students to determine the distance the ball dropped vertically for each time interval. Subtract the distance the ball dropped in one interval from the one before it. Have students record these values.

Have students plot two graphs for each path: a vertical distance graph (x = time; y = vertical distance) and a horizontal distance graph (x = time; y = horizontal distance). Discuss their results as a class.

Evaluate

1. Compare the distance a ball falls during the first interval after it is dropped with the distance it falls during the last interval. (It falls farther during the second.) Why? (It has accelerated and is falling faster.)

2. Satellites in close circular orbit fall 4.9 m during each second of orbit. How can this be if the satellite does not get closer to the earth? (The earth falls—slopes—away from the satellite at exactly the same rate.)

3. If you stopped an earth satellite dead in its tracks, it would simply fall to the earth. Why, then, don't the geostationary communication satellites that "hover motionless" above the same spot on earth simply crash into the earth? (They are still moving—orbiting the earth—at the same rate the earth is rotating.)

Try This

Fill a toy water rocket partially with water and then, using the combination pump/launcher, pump air into the rocket along with the water to fire it. Using this combination, test several variables. First, vary the amount of water and note its effect on the trajectory. Second, determine how the number of pumps of air affects the trajectory. Finally, using a fixed amount of water and number of pumps, vary the launch angle and observe its effect on the trajectory. In all trials, time the flight for each and relate it to the other variables..

Isaac Newton first proposed the idea of objects orbiting the earth in the late 1600s. In the *Principia*, in which he first published his "Universal Law of Gravitation," there is a diagram of a cannon on a tall mountain on the earth. The diagram shows the launch of several different balls at several different velocities and where they would land. Newton proposed that if there were a powerful enough cannon on a tall enough mountain, it could launch a ball into near-earth orbit. You can find a similar diagram on the CD-ROM (Resource Button D). Research Newton's ideas and report to the class.

Around and Around

Activity Sheet 2

Name ______________________________ **Class Period** __________

What you're going to do

You're going to investigate the motion of a projectile, including the relationship between horizontal and vertical velocity of a projectile.

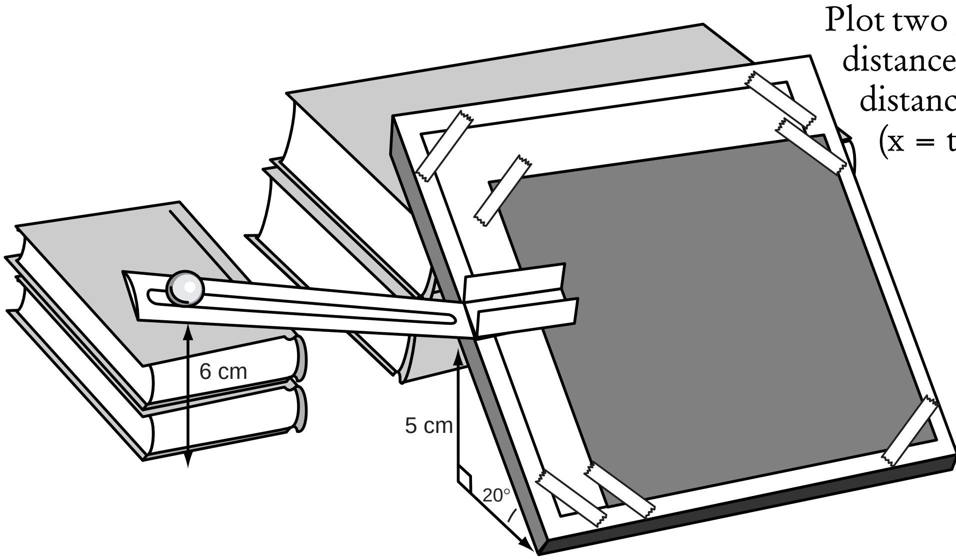
How to do it

Work with a small group of classmates. Your teacher will help you set up an apparatus like the one shown in the diagram.

Recording your data

Follow your teacher's instructions for recording data and plotting graphs. For each of the three launchings, record the horizontal and vertical distance the projectile traveled during each interval. Record the distances in centimeters.

Plot two graphs for each path: a vertical distance graph (x = time; y = vertical distance) and a horizontal distance graph (x = time; y = horizontal distance).



What did you find out?

For each path, was there any change in the horizontal distance the ball traveled in each time interval?

For each path, was there any change in the vertical distance the ball traveled in each time interval?

What conclusions can you draw about the relationship between the different trajectories?

Activity 3

Faster and Faster

What is acceleration? What determines the acceleration of a falling object? Is acceleration constant? What is velocity? Does velocity affect the acceleration of a falling object?

Getting Ready

Overview

Students listen to falling weights and hear how they accelerate. By adjusting the distance the weights fall, they explore the relationship between distance and acceleration as objects fall toward Earth.

Objectives

After completing this activity, students will be able to—

- describe the acceleration of falling objects
- predict acceleration using velocity and distance traveled

Time Needed

Preparation: Approx. 10 min.
Classroom: Approx. 45 min.

Materials

Each team of students:

- 14 split shot fishing weights
- 2 lines of monofilament fishing line, each about 2.5 meters long
- cookie sheet or metal pan
- pliers
- books to place under the cookie sheet
- adhesive tape

Important Terms

free fall—The motion of a falling body being pulled by the force of gravity.

speed—The distance an object travels over a set amount of time; the faster it moves the more speed it has.

NEWTON'S APPLE Multimedia

Gravity

Here's How

Video Clip 4
(16:07 to 18:19)—David Heil learns first-hand that two objects fall at the same speed by solving the classic "Monkey and Hunter" riddle. (2 min. 12 sec.)

Guide on the Side

- You may wish to begin the lesson by viewing the Introduction from the Video Menu on the CD-ROM [08:26-09:23]. Find out what students already know about rockets. As a class, discuss the questions posed by Eileen Galindo.
- If you have deaf students in your class, have them place their hands on the cookie sheets to feel the impact of each weight as it hits the surface.
- In Part Two, the ideal ratios for the weights are: the first weight 5 cm from cookie sheet; the next weight 15 cm from the first weight; the third weight 25 cm from the second;fourth weight 35 cm from the third;fifth weight 45 cm from the fourth;the sixth weight 55 cm from the fourth; and the last weight 65 cm from the sixth.
- To make the weights hit the pan in equal intervals, they must be positioned on the string the distance they will fall, according to the formula $d=1/2\,g\,t^2$, where g is the acceleration of gravity, 32 ft/sec^2.
- Students will hear the same result as long as the position on the string is proportional to the square of the number of the weight. The distances are given here for $5\,n^2$ with n ranging from 1 to 7. If possible, students should experiment with varying lengths of strings and differing relationships. If students grasp that objects accelerate in proportion to the square of the elapsed time, they will gain a new insight into what speeds falling bodies achieve in only a few seconds. Jumping off bridges is very dangerous!
- If time allows, you may wish to have students view the entire *Newton's Apple* video segment on gravity.

Preparation

- Set up the computer to play the CD-ROM (or set up the VCR and cue the tape).
- Gather the necessary materials for the student experiments.
- Make copies of Activity Sheet 3 for each student.
- Review the Background information on page 24.

Engage (Approx. 15 min.)

Show students Video Clip 4 [16:07 to 18:19]. Ask students what principle this demonstrates. Are they falling at the same speed? (yes; the speed of the vertical drop is the same, even though one ball goes a greater distance overall.)

Ask students whether they think a falling object picks up additional speed as it drops toward Earth. What makes them think so? Ask them for examples that lead them to believe this. (It is safe to catch a stone dropped from a meter or two, but not one dropped from a high building.)

Ask students if they can think of a way that they could demonstrate that an object accelerates when it is in free fall. Explain that in free fall, gravity is the only force affecting the object and there is no air resistance. A classroom experiment cannot be done in the absence of air resistance, so students will have to ignore that variable in their experiments.

Explore (Approx. 30 min.)

Have the students work in small groups. Tell them they are going to explore the acceleration of an object as it falls.

Part One

Have the students attach one end of a fishing line to a cookie sheet with tape. Tell them to clamp seven split shot fishing weights onto the line at even intervals 40 cm (16in.) apart. Then, place the cookie sheet on books. (This allows for maximum clatter.) Direct one student in each group to stand on a chair, hold the line up taut directly above the cookie sheet, and then drop the end of the line. Students listen and record their observations.

Students should do this several times to verify their observations.

Part Two

Challenge students to construct a second line with a second set of seven weights in such a way that the weights will land at regular intervals on the cookie sheet. Have them listen to the dropping weights and record their observations.

Activity 3

Evaluate

1. How did your group determine how to space the weights for the second part of the activity? (Answers will vary. Have groups compare and discuss their experiences.)

2. If an object has a greater speed, does it necessarily have a greater acceleration?

Explain, using examples. (No, speed is a constant relationship between time and distance; acceleration is a change in speed.)

3. Explain why weights increasingly further from the ground land at equal intervals of time. Are the higher weights falling faster when they hit the cookie sheet? (Yes.) Why? (Because of gravity, falling objects accelerate.)

Try This

Observe fly balls in a televised baseball game. Which falls to the ground faster, a high fly ball or a pop fly? If a high fly ball has more velocity going up, does it take longer than a pop fly to fall to the ground?

Adjust a faucet or other source of water so that drops come out at regular intervals. Allow the drops to fall a distance of 1meter or more. Notice that the drops at the bottom are farther apart than the drops higher up. The best way to see this is in a dark room and by shining a stroboscope on the column of drops. The stroboscope makes it possible to “freeze” the motion of the drops and dramatically show the variation in distance between them.

If you have access to a video camera you can videotape a falling object. To do this, find about 2.5 vertical meters of wall space and cover it with black paper about 0.5 meters wide. Using masking tape, mark and label every 10 cm on the paper. Then, with the video camera mounted on a tripod and pointed at the paper, drop a tennis ball and videotape its fall. The video may then be played and analyzed frame by frame to watch and record the motion of the ball. You may then wish to drop and videotape a “packing peanut” and compare its motion to that of the tennis ball. The effect of air resistance will be readily apparent when watching the video of this motion.

FASTER AND FASTER

Activity Sheet 3

NAME________________________________ CLASS PERIOD ____________

WHAT YOU'RE GOING TO DO

You're going to investigate how objects accelerate as they fall and the relationship between objects falling different distances.

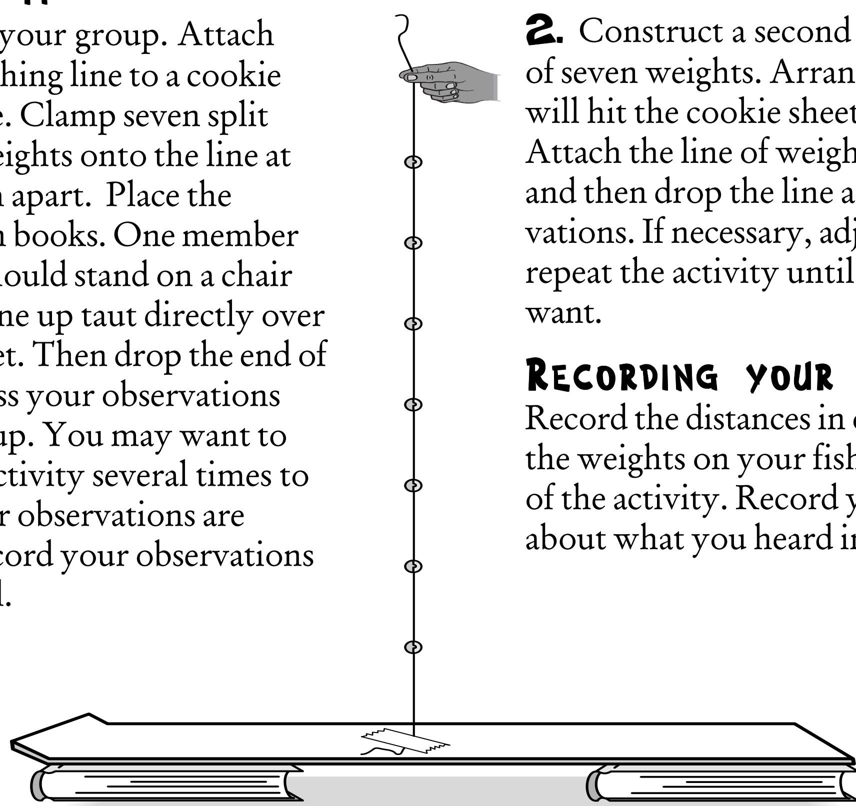
HOW TO DO IT

1. Work with your group. Attach one end of a fishing line to a cookie sheet with tape. Clamp seven split shot fishing weights onto the line at intervals 40 cm apart. Place the cookie sheet on books. One member of the group should stand on a chair and hold the line up taut directly over the cookie sheet. Then drop the end of the line. Discuss your observations with your group. You may want to perform this activity several times to make sure your observations are consistent. Record your observations in your journal.

2. Construct a second line with a second set of seven weights. Arrange the weights so they will hit the cookie sheet at regular intervals. Attach the line of weights to the cookie sheet, and then drop the line and record your observations. If necessary, adjust the weights and repeat the activity until you get the result you want.

RECORDING YOUR DATA

Record the distances in centimeters between the weights on your fishing line for both parts of the activity. Record your observations about what you heard in both trials.



(NOTE: The illustration is not drawn to scale.)

WHAT DID YOU FIND OUT?

What did you hear? Are some of the weights falling faster than others? Did gravity pull more strongly on some objects than on others?

What do your observations tell you about acceleration of falling objects?

In order to achieve the goal of weights hitting the cookie sheet at regular intervals, did you have to space the weights closer together or farther apart?

Explain how your spacing allowed the weights to hit the ground at regular intervals. If time allows, see if you can determine a formula for the position of the weights on the string.

Credits

CD-ROM PROJECT STAFF

KTCA TV, NEWTON'S APPLE MULTIMEDIA

Dr. Richard Hudson
Director of Science Unit

David Heath
Lee Carey
Curriculum Development Managers

Cori Paulet
Paddy Faustino
Curriculum Development Coordinators

Edward Voeller
Lesson Editor

Jeffrey Nielsen
Additional Resources Coordinator

Michael Watkins
Susan Ahn
Sandy Schonning
David Yanko
Production Managers

Lisa Blackstone
Erin Rasmussen
Producers

Steve Flynn
Producer/Editor/Videographer

Lesley Goldman
Danika Hanson
Kim MacDonald
Associate Producers

Janet Raugust
Screen Designer

Ben Lang
Production Assistant

Linda Lory-Blixt
Field Test Coordinator

Michael Johnston
Joe Demuth
Short Course Facilitators

Nick Ghitelman
Intern

NEBRASKA EDUCATIONAL TELECOMMUNICATIONS

John Ansorge
Interactive Media Project Manager

Andy Frederick
Interactive Media Designer

Christian Noel
Interactive Media Project Designer

Kate Ansorge
Intern

GREAT PLAINS NATIONAL

Tom Henderson
Jackie Thoelke
Diane Miller
Diedre Miller
Guide Design and Production

NATIONAL ADVISORY BOARD

Rodger Bybee
National Academy of Sciences

Richard C. Clark
Minnesota Department of Education, Retired

Dave Iverson
Imation Enterprises Corporation
Vadnais Heights, MN

Dr. Roger Johnson
University of Minnesota

Dr. Mary Male
San Jose State University

Dr. Carolyn Nelson
San Jose State University

Lori Orum
Edison Language Academy
Santa Monica, CA

Janet Walker
B.E.T.A. School
Orlando, FL

Michael Webb
New Visions for Public Schools
New York, NY

SENIOR ADVISORS

David Beacom
National Geographic Society

Dr. Judy Diamond
University of Nebraska State Museum

Dr. Fred Finley
University of Minnesota

Greg Sales
Seward Learning Systems, Inc.
Minneapolis, MN

LESSON WRITERS

Jon Anderson
Fred Bortz
Sara Burns
Pam Burt
Jim Dawson
Russ Durkee
Vickie Handy
Lorraine Hopping Eagan
Sheryl Juenemann
Cheryl Lani Juarez
Mike Maas
Mike Mogil
Bruce T. Paddock
Linda Roach
Phyllis Root
Zachary Smith
Sheron Snyder
Caren Stelson
Steve Tomecek
Edward Voeller
Anne Welsbacher

REVIEWERS

Charles Addison
Minnesota Earth Science Teacher's Association

Micheal John Ahern
Mentor Teacher, Science and Math
Redwood, CA

Scott Alger
Watertown-Mayer Middle School
Watertown, MN

Zan Austin
Strickland Middle School
Denton, TX

Jon Barber
North Oaks, MN

Rebecca Biegon
Macalester College
St. Paul, MN

Juan Cabanella
University of Minnesota

Rolando Castellanos
St. Paul Academy and Summit School
St. Paul, MN

Sarah Chadima
South Dakota Geological Survey

Dr. Orlando Charry
University of Minnesota - Dept. of Surgery

Kristine Craddock
Mexico High School
Mexico, MO

Ruth Danielzuk
American Cancer Society

Steve Dutczak, Ph.D.
NASA

Richard Erdman
Venice High School
Los Angeles, CA

Bruce Fisher
Fortuna Elementary
Fortuna, CA

Mike Garcia
University of Hawaii

Chris Gregg, A.B.O.C.
Inver Grove Heights Family Eye Clinic
Inver Grove Heights, MN

Rick Grigg
University of Hawaii

Deborah Harden
San Jose State University

Gloriane Hirata
San Jose Unified District

Margaret K. Hostetter, M.D.
University of Minnesota

Neil F. Humphrey
University of Wyoming

Lisa Hunter, Ph.D.
University of Minnesota

Sally Jenkins
Roosevelt Elementary
Minot, ND

Bruce Jones
The Blake School
Hopkins, MN

Leslie Kline
Metcalf Junior High
Burnsville, MN

Tom Krinke
Maple Grove Junior High
Maple Grove, MN

Frank Lu
University of Texas-Arlington

Cynthia MacLeod
Sabin Early Childhood Education Center
Portland, OR

Robert March
University of Wisconsin-Madison

Shannon Matta, Ph.D.
Minneapolis Medical Research Foundation

Ken Meyer
Coon Rapids High School
Coon Rapids, MN

Lou Mongler
Mexico High School
Mexico, MO

NEWTON'S APPLE Multimedia

Credits

Candy Musso
Vineland Elementary School
Pueblo, CO

John Musso
Pueblo Technical Academy
Pueblo, CO

Debbie Nelson
Bay Trail Middle School
Penfield, NY

Jack Netland
Maple Grove High School
Maple Grove, MN

Joyce Nilsen
Technology Learning Campus
Robbinsdale, MN

Ingrid Novodvorsky
Mountain View High School
Tucson, AZ

Jon Pedersen
East Carolina University

MaryBeth Peterson
Roosevelt Elementary
Minot, ND

Alberto Ramirez
Spanish Translator
Miami, FL

Bev Ramolae
Technology Learning Campus
Robbinsdale, MN

Brad Randall
Osseo Area Schools
North Maple Grove, MN

Gina Roetker
Strickland Middle School
Denton, TX

Fernando Romero
University of Houston

Dr. Lawrence Rudnick
University of Minnesota

Hank Ryan
Mounds View High School
Arden Hills, MN

Jan Serie
Maclester College
St. Paul, MN

Larry Silverberg
North Carolina State University

Jaine Strauss, Ph.D.
Macalester College
St. Paul, MN

Thomas Walsh, Ph.D.
University of Minnesota

Steve Wartburg
Fortuna Elementary
Fortuna, CA

Randy Yerrick
East Carolina University

FIELD TESTERS

Scott D. Bell
Chaminade College Prep
St. Louis, MO

Laura S. Berry
Orland Jr. High
Orland Park, IL

Lance Brand
Driver Middle School
Winchester, IN

Lorene A. Chance
East Ridge Middle School
Russellville, TN

Elizabeth Cordle
Montgomery Middle School
El Cajon, CA

David Eggebrecht
Kenosha Unified
Kenosha, WI

Dennis L. Engle
East Lawrence High School
Trinity, AL

Dave Fleischman
Spring Valley Middle School
Spring Valley, CA

John Frugoni
Hillsdale Middle School
El Cajon, CA

Linda Furey
Rising Star Middle School
Fayetteville, GA

Rosemary Gonzales
Greenfield Middle School
El Cajon, CA

Liz Hendrickson
Driver Middle School
Winchester, IN

Bruce M. Jones
The Blake School
Hopkins, MN

Dave Kahl
Wadena-Dear Creek High School
Wadena, MN

Theresa Kistner
Helen C. Cannon Middle School
Las Vegas, NV

Craig Klawitter
Wadena-Dear Creek High School
Wadena, MN

Linda Love
Hillsdale Middle School
El Cajon, CA

Virginia Madigan
Montgomery Middle School-El Cajon
El Cajon, CA

Steven D. McAninch
Park Forest Middle School
State College, PA

Robert J. Nicholson
Von Tobel Middle School
Las Vegas, NV

Jim Parker
Spring Valley Middle School
Las Vegas, NV

Joyce Perkins
Whatcom Day Academy
Bellingham, WA

Sharon Reynolds
Independence Secondary School
Christiansburg, VA

Judy Stellato
Jerling Jr. High
Orland Park, IL

Ralph V. Thomas
Helen C. Cannon Middle School
Las Vegas, NV

Robin Tomasino
Masconomet Regional Jr. High
Topsfield, MA

Donna Treece
East Ridge Middle School
Russellville, TN

Darrell Warren
Von Tobel Middle School
Las Vegas, NV

Janis Young
Montgomery Middle School
El Cajon, CA

SPECIAL THANKS

Partners

American Psychological Association
750 First Street, NE
Washington, DC 20002
(202) 336-5500
http://www.apa.org

Minnesota Department of Children, Families and Learning
Capitol Square Building
550 Cedar Court
St. Paul, MN 55101
(651) 296-6104
http://clf.state.mn.us

Fender Musical Instruments Corporation
7975 North Hayden Road
Suite C-100
Scottsdale, AZ 85258
(606) 596-7242
http://www.fender.com

W.L. Gore & Associates, Inc.
551 Paper Mill Road, P.O. Box 9206
Newark, DE 19714-9206
(302) 738-4880
http://www.gore.com

National Science Foundation
4201 Wilson Boulevard
Arlington, VA 22230
(703) 306-1234
http://nsf.gov

Regents of the University of Minnesota, Twin Cities
General Biology Program
http://biomedia.umn.edu

Waltham
Consumer Affairs, P.O. Box 58853
Vernon, CA 90058
(800) 525-5273
http://www.waltham.com

Consultants

Dave Arlander
John Marshall High School
Rochester, MN

Bobbie Faye Ferguson
NASA

Chuck Lang
University of Nebraska

Maynard Miller
Juneau Ice Field Research Project

John Olson
Arlington High School
St. Paul, MN

Dr. Helen M. Parke
East Carolina University

NOTES

NOTES

NEWTON'S APPLE® Multimedia

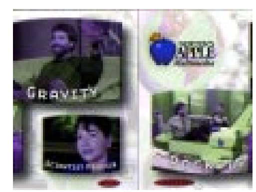
AT LAST, a supplemental middle school science curriculum that helps you meet the challenges of today's science classroom. The program engages students by incorporating segments from the award-winning *Newton's Apple* television show into hands-on/minds-on activities. Each lesson plan helps you integrate the technology using an inquiry-based approach. A variety of assessment options allow you to gauge student performance. And the entire program is correlated to the National Science Education Standards.

EACH CURRICULUM MODULE CONTAINS:

- a CD-ROM with two *Newton's Apple* segments, a video profile of a working scientist, and additional audio/visual resources
- a teacher's guide with lesson plans for six inquiry-based activities
- a *Newton's Apple* videotape







38 topics in 19 modules!! Choose the curriculum modules that benefit your needs.

Physical Science
Air Pressure/Domed Stadiums
Electric Guitars/Electricity
Gravity/Rockets
Infrared/Reflection

Sports Physics
Hang Gliders/Surfing
High Wire/Skateboards
Spinning/Water-skiing

Life Science and Health
Antibiotics/Cancer
Blood Typing/Boner
DNA/DNA Fingerprinting
Hearing/Human Eye
Nicotine/Smiles

Earth and Space Science
Clouds/Weathering
Dinosaur Extinction/Earthquakes
Everglades/Sewers
Geothermal Energy/Glaciers
Greenhouse Effect/Ozone
Meteors/Solar Eclipses
Phases of the Moon/The Sun

Individual Packages: $49.95
Three-CD collection: $119.45
Four-CD collection: $159.95

To order by mail:
GPN
P.O. Box 80669
Lincoln, NE 68501-0669

To order by phone, call toll-free:
1-800-228-4630
Fax your order to:
1-800-306-2330
E-mail your order to:
gpn@unlinfo.unl.edu

Order today!

Distributed by

GPN

Box 80669, Lincoln, Nebraska 68501 — 800-228-4630